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An Investigation of Using Burn Barrel Technology to Dispose of Shipboard-Generated (MARPOL V) Wastes

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AN INVESTIGATION OF USING BURN BARREL TECHNOLOGY TO DISPOSE OF SHIPBOARD-GENERATED (MARPOL V) WASTES

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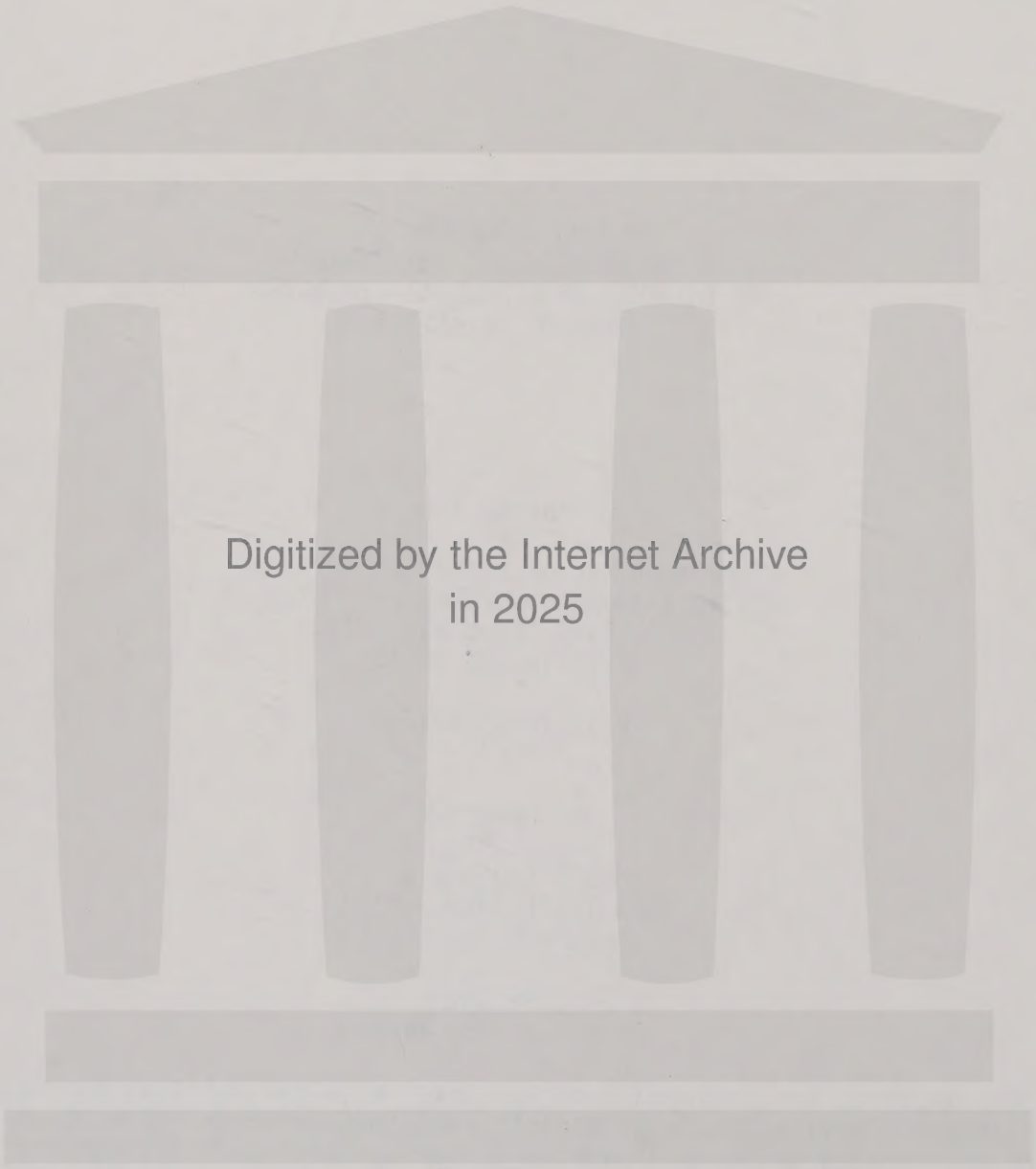
This document was prepared under contract with the National Marine Fisheries Service, National Oceanic and Atmospheric Administration. It is intended to be used as a guide for vessel owners and operators who wish to utilize their own burn barrels. Conceptual designs provided in this document may not be suitable for specific vessels. The services of a qualified engineer should be used to apply the guidance provided in this document to vessel-specific conditions.



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EXECUTIVE SUMMARY

U.S. laws and international treaties now restrict the dumping of shipboard-generated wastes at sea. It has been reported that a variety of vessels are currently utilizing low technology "burn barrels" to dispose of their wastes at sea. An investigation was conducted to evaluate the technical feasibility, safety, and potential environmental impacts of using burn barrels to dispose of ship wastes. The burn barrels in use are simple, "low tech", and similar to those barrels commonly used to burn household trash during the 1950s. Incineration of wastes in special marine incinerators was specifically excluded from this study.

It should be stressed that NOAA and SCS are not advocating the burn barrel technique. However, under present regulatory authority, such technology is permissible and actively being utilized. It is the purpose of this document, then, to provide guidelines which will enable legal disposal of shipboard wastes with proper consideration and care given to protecting the environment, shipboard personnel, and the vessel itself.

Guidelines for the design, construction, and operation of burn barrels were developed. Primary considerations were optimizing combustion (as far as practical in a unit with no moving parts); the types of wastes to be burned; operator safety; and fire prevention.

The regulations that might affect the use of burn barrels were also evaluated. These included regulations addressing marine pollution prevention, Coast Guard rules controlling open fires, and Dept. of Agriculture rules for wastes contaminated by food from foreign countries. Other regulations evaluated were Federal, state, and local air pollution control standards; building codes for wood-burning stoves; and occupational safety and health rules.

Although there are regulations that would limit the use of burn barrels, an even greater concern is fire. Marine insurers were contacted to obtain their views about installing burn barrels aboard vessels they might insure. In addition, potential environmental impacts from air and ash emissions were considered, along with health and safety risks to burn barrel operators.

Burn barrels are technically feasible and when properly used, appear to comply with existing environmental or marine regulations. It is believed that when operated according to the suggested guidelines, they can provide a safe, convenient, and low cost alternative to either on-shore disposal or incineration of shipboard-generated wastes.

SECTION 1

INTRODUCTION

BACKGROUND

Traditionally, shipboard waste has been dumped over the side or "deep-sixed" without regard as to the impact of the waste on marine life or navigation. However, due to the increased amount of vessel traffic on the world's oceans as well as the amount of non-degradable waste being discharged, this method of disposal is no longer acceptable. Indeed, marine debris is now being recognized as a growing problem, threatening marine life, beaches, and vessel safety worldwide. For example, the news media has presented vivid examples of both marine birds and fish entangled or choked by plastic retainer rings from beverage six-packs and fishing line, as well as marine mammals and turtles trapped by synthetic nets or strapping bands. Beaches worldwide are being polluted by garbage washing ashore. Vessels are increasingly disabled by fouled propellers and engine intakes due to derelict ropes, lines, plastic sheeting, and other persistent marine debris.

Various treaties and Federal laws have been enacted within the last ten years to address these persistent marine debris problems. One of the most important of these is an international agreement developed by the Assembly of the International Maritime Organization (IMO) at the International Conference on Marine Pollution in London. Annex V of the agreement, entitled "Regulations for the Prevention of Pollution by Garbage from Ships", or MARPOL Annex V, prohibits dumping into the sea of "persistent plastics and other persistent synthetic materials such as netting and ropes, which float or remain in suspension, causing them to interfere with fishing, navigation, or other legitimate uses of the sea" (Report of the Interagency Task Force on Persistent Marine Debris, May 1988). Thus, the primary purpose of MARPOL is to prevent ships from polluting the marine environment by discharging harmful substances.

The United States signed this agreement in 1973, ratified Annex V on November 5, 1987 and passed implementing legislation, Public Law 100-220, on December 30, 1987. Title II of this law, "The Marine Plastic Pollution Research and Control Act of 1987", amends the existing "Act to Prevent Pollution from Ships" (APPS) to incorporate the requirements of MARPOL Annex V. This law, which came into effect on December 30, 1988, restricts at-sea discharge of garbage, and bans all at-sea disposal of plastics and other synthetic materials.

Specifically, the regulations will only allow at-sea disposal of dunnage, lining, and packing materials if the ship is more than 25 nautical miles from shore and the dumping of food waste, paper products, rags, glass, metal, bottles, crockery and other similar refuse if the ship is more than 12 nautical miles from shore. Additionally, the law requires adequate reception facilities, capable of handling garbage from ships, be available at all ports. Table 1, MARPOL Annex V: Garbage Disposal Restrictions, presents waste handling restrictions dictated by MARPOL Annex V.

Table 1. MARPOL Annex V: Garbage Disposal Restrictions

GARBAGE	ALL VESSELS EXCEPT OFFSHORE PLATFORMS AND ASSOCIATED VESSELS		OFFSHORE PLATFORMS AND ASSOCIATED VESSELS[1]
	Outside Special Areas *	In Special Areas[2]	
Plastics—includes synthetic ropes, fishing nets, and plastic bags	Disposal prohibited	Disposal prohibited	Disposal prohibited
Floating dunnage, lining and packing materials	Disposal prohibited less than 25 miles from nearest land	Disposal prohibited	Disposal prohibited
Paper, rags, glass, metal, bottles, crockery and similar refuse	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited	Disposal prohibited
Paper, rags, glass, etc., comminuted or ground[3]	Disposal prohibited less than 3 miles from nearest land	Disposal prohibited	Disposal prohibited
Food waste not comminuted or ground	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited
Food waste comminuted or ground[3]	Disposal prohibited less than 3 miles from nearest land	Disposal prohibited less than 12 miles from nearest land	Disposal prohibited less than 12 miles from nearest land
Mixed refuse	Varies by component[4]	Varies by component[4]	Varies by component[4]

Adapted from U.S. Federal Register *Advance Notice of Proposed Rulemaking*, June 24, 1988, p. 23887.

[1]Includes all fixed or floating platforms engaged in exploration or exploitation and associated offshore processing of seabed mineral resources, and all vessels alongside or within 500 m (approximately one-third mile) of such platforms.

[2]The Mediterranean, Baltic, Red, and Black seas and the Persian Gulf.

[3]Must be able to pass through a screen with a mesh size no larger than 25 mm.

[4]When substances having different disposal or discharge requirements are mixed, the more stringent disposal requirement shall apply.

*nautical miles

With the advent of this law, most ships must find an alternate to ocean dumping of their wastes. Marine incinerators, compactors, and grinders (comminutors) may not be economically viable for a particular vessel, or there may be inadequate space for their installation. One method of dealing with ships' wastes that has been used and may receive greater attention in the future is the "burn barrel". An example of a burn barrel is a 55-gallon drum with holes cut in the side to allow combustion air to enter, similar to those in widespread use in the 1950s to burn residential garbage.

The National Oceanic and Atmospheric Administration (NOAA) has sponsored this study to evaluate the safety and feasibility of the burn barrel method of at-sea disposal. It was the intent of this study to provide vessel operators with clear information on the operation, safety and effectiveness of this disposal method.

OBJECTIVES OF THE STUDY

The objectives of the investigation were as follows:

1. To evaluate the technical, environmental, and safety aspects and viability of using low temperature burn barrels to dispose of shipboard-generated wastes;

2. To provide, if possible, a solution that is convenient, cost-effective, and safe;

3. To emphasize the fire and safety hazard aspects of the technology and note the air pollution and regulatory aspects; and

4. To provide design and operating guidelines for burn barrels.

SCOPE AND LIMITATIONS OF THE STUDY

To attain these objectives, this study focused only on burn barrels and did not explore other means of waste disposal. It was not the intent of this study to promulgate new regulations or to exhaustively research the relationship of existing environmental regulations and their impacts on burn barrels.

The scope of the study did not permit detailed scale design of a prototype burn barrel. Such an undertaking would have been complicated by having to develop a single design suitable for a variety of vessels and operating conditions. In lieu of a prototype design, specific design criteria and guidelines were developed. These included recommended construction materials, size, ventilation, placement, and loading. Human health and safety concerns such as burns, smoke inhalation, fire hazards and ingestion of food cooked over burn barrels were also considered. Additionally, environmental concerns such as ash disposal, pitting or corrosion of metal, and air emissions were examined.

DOCUMENTATION

Two separate documents were generated from this study. The first, entitled "Operating and Safety Guidelines for Use of Burn Barrels to Dispose of Shipboard-Generated (MARPOL V) Wastes", was intended for use by vessel owners and operators and is a separate document. The second document produced is this technology background document, "An Investigation of Using Burn Barrel Technology to Dispose of Shipboard-Generated (MARPOL V) Wastes". This document presents the research and details the evaluations which lead to the recommendations found in the Guidelines.

SECTION 2

THE MARINE DEBRIS PROBLEM

MARINE DEBRIS

Human-generated marine debris is derived from two sources: shore-side populations and sea-going vessels/platforms. Wastes from shore-side (land) include windblown litter, wastes washed down sewers and storm drains, and municipal solid waste and hospital wastes that have been improperly or illegally disposed of at sea.

Sea-going vessels/platforms discharge an estimated 6,000,000 metric tons of solid waste, consisting primarily of man-made objects of metal, glass, wood, rubber, plastic, paper, and cloth. This includes some 100,000 metric tons of synthetic fishing gear such as nets, pots, lines, floats, and webbing which has either been intentionally discarded or inadvertently lost. It has been estimated that ships discharge some 4,800,00 metal, 300,000 glass, and 450,000 plastic containers *every day* (National Academy of Sciences, 1975).

Plastics, which tend to float, constitute the most noticeable type of marine debris. Furthermore, because of their persistence (resistance to degradation), transportability, and risks to both vessels and marine life, shipboard-generated plastics have become a significant disposal problem.

HAZARDS CAUSED BY MARINE DEBRIS

Hazards to Marine Life

Information is readily available concerning the dangers to marine life posed by man-made debris (e.g., see Proceedings of the Workshop on the Fate and Impact of Marine Debris, 1984). For example, there are several reports documenting that marine birds, mammals, fish, and invertebrates have been endangered, harmed, or killed by the following mechanisms involving marine debris:

- ingestion of objects such as plastic bags and styrofoam pellets that resemble jellyfish and fish eggs, the natural food of sea turtles and marine birds, resulting in strangulation or starvation;
- entanglement or entrapment by discarded or lost fishing gear such as crab and lobster pots, nets, monofilament line, and buoy lines, resulting in strangulation or starvation;
- entanglement or entrapment by beverage six-pack yokes, plastic bags, strapping, and other plastic articles, resulting in strangulation or starvation.

Hazards to Vessels

Marine debris can also cause damage to both vessels and their associated equipment. Survey data developed under the Marine Refuse Disposal Project in Newport, Oregon indicates the following types of problems experienced by commercial fishermen (listed in decreasing order of frequency):

- propeller fouled by nets
- plastic or netting entangled in trolling/long lines
- propeller fouled by rope
- plastic bags in engine intakes
- propeller fouled by unspecified plastics
- line fouled in gear
- trawl net snagged/damaged by man-made object
- crab water pump fouled by plastic
- plastic in engine intake.

Estimated monetary damages ranged from $20 to $13,000. In some cases, a load of valuable crab could have been lost. In all cases, at-sea time was lost in diagnosing or repairing the damage. Survey data from the same project found similar experiences among sports fishing vessels, although the monetary damages were smaller.

SHIPBOARD WASTE GENERATION RATES

Shipboard Waste Studies

Accurate estimates of the amount of shipboard waste generated are difficult to obtain. Numerous studies have attempted to quantify waste generation aboard a variety of vessels. In the early 1970's, the International Maritime Organization (IMO) developed data on shipboard waste generation from American, Japanese, and Soviet vessels. The Coast Guard has incorporated the IMO's formulas for estimating waste volume into its 1988 Advance Notice of Proposed Rulemaking. However, since the time of that study, there has been a widespread increase in the amount and type of plastics used, particularly in packaging, which could affect the type and amounts of wastes generated aboard ships, therefore the estimates may not be accurate. Additionally, the limited data from only three countries may curb their applicability. Finally, the formulas include harbor, inland, and coastal waterway vessels which are unlikely to consider burn barrels or other non-land disposal methods.

In another attempt to estimate the amount of shipboard waste generated, the 1971 Naval Shipboard Refuse Study analyzed the waste generated by 81 military ships. Data from this study may not be applicable to non-military vessels, especially because of their relatively long trip duration (often over 30 days) and efficiency of packaging food (hence, less packaging waste) for large (typically over 200 person) crews. A 1988 study of the USS O'Bannon appeared to substantiate the findings of the earlier Navy study, except for finding a 20-fold increase in plastic waste since the 1971 study.

In 1975, the U.S. National Academy of Sciences reviewed available data to assess the potential impact of pollutants on the ocean environment. This study incorporated the results of a study of waste generation aboard U.S. Navy vessels. One notable conclusion of the NAS study was an estimate that approximately 56 percent of the waste generated by commercial shipping vessels was food or vegetable wastes.

A recent (1988) study for the Port of Seattle estimates an international garbage generation rate of 4.4 lbs/person/day for cargo ships and 5.3 pounds for passenger ships.

In summary, estimates for generation of various solid wastes aboard ship seem to range from approximately three to five pounds per person per day. However, while most of these wastes could be burned in a burn barrel, there is little reason to do so. For example, cans and bottles are non-combustible and will be unaffected by the burning process; they could be disposed of by dumping in designated areas per the MARPOL V regulations. While food wastes can be reduced in volume through burning, they too can be dumped in MARPOL-approved areas. Thus, only about one to two pounds per person per day of plastics, packaging wastes, paper, cardboard, and wood are suitable for burning.

SECTION 3

REGULATORY CONSIDERATIONS

MARINE POLLUTION REGULATIONS

To reduce pollution of the ocean and the hazards of marine debris, the U.S. has signed an international treaty and promulgated several Federal laws. These include:

1. Regulations for the Prevention of Pollution by Garbage from Ships (Annex V of the International Convention for the Prevention of Pollution by Ships, 1973): Also known as MARPOL Annex V, this treaty attempts to eliminate the discharge of plastics, including synthetic fishing nets, and control the dumping of other ship-generated garbage into the marine environment. The Regulations prohibit dumping of plastics anywhere in the ocean, and set limitations (approved discharge areas) where other types of garbage may be dumped at sea.

2. Public Law 100-220, The Marine Plastic Pollution Research and Control Act of 1987: This law is the implementing U.S. legislation for the requirements of MARPOL Annex V. The law came into effect on December 31, 1988, and restricts at-sea discharge of garbage to certain zones and bans all at-sea disposal of plastics. Table 1 indicates how certain types of shipboard waste should be disposed, and in what locations.

AGRICULTURAL REGULATIONS

To prevent the spread of infectious disease and pests which could harm domestic plants, animals, and crops, the U.S. Dept. of Agriculture promulgated Title 7, Part 330, Federal Plant Pest Regulations. These laws require that food wastes or food-contaminated garbage unloaded from ships arriving from foreign ports (except Canada) be contained in approved closed, leak-proof receptacles under the direction of the Animal and Plant Health Inspection Service (APHIS). Such wastes must be disposed of by incineration, steam sterilization, or grinding and subsequent discharge into a sewage treatment system.

PLASTICS REGULATIONS

Because of their persistent nature and the potential damage to marine life, plastics in the marine environment are strictly regulated. Regulations prohibit the dumping of plastics, including synthetic ropes, fishing nets, and plastic garbage bags, anywhere in the ocean. Thus, plastics may only be disposed of by:

- burning (incinerating) at sea; or
- if contaminated with food from a foreign port (except Canada), placed in a sealed container and disposed of in port under USDA supervision; or
- if not contaminated with food, disposed of in port with other non-food contaminated garbage.

If the ash resulting from burn barrel operations does not contain particles larger than one inch, and if it does not contain any unburned plastic, the ash may be discharged from a vessel at least three nautical miles from shore. If the ash particles exceed one inch and do not contain unburned plastic, the ash may be discharged beyond 12 nautical miles from shore. Unburned plastic globules in the ash cannot legally be discharged at sea and must, therefore, be disposed of ashore.

COAST GUARD REGULATIONS

Title 46 of the Code of Federal Regulations (CFR) sets forth regulations for the Coast Guard. Within 46 CFR, vessels are categorized into several broad categories: tank vessels; passenger vessels; small passenger vessels; cargo and miscellaneous vessels; bulk and dangerous cargo; uninspected vessels; and oceanographic vessels. Each broad type of vessel is subject to specific regulations which the Coast Guard is charged with enforcing; except when a vessel is specifically exempt from inspection.

Vessels exempt from inspection include, but are not limited to, fishing craft; yachts; vessels over 65 feet in length carrying less than 12 passengers; and documented cargo or tank vessels issued a permit to carry not more than 16 persons in addition to the crew. For those vessels subject to inspection under various Coast Guard regulations, there may be special provisions which determine whether or not vessels should use low technology burn barrels. The following summarizes which vessels could use barrels:

VESSEL TYPE	BURN BARREL USAGE
Tank (Subchapter D)	Not allowed per Subpart 35.30-5, (Prohibition against open lights and fires other than the boiler and galley)
Cargo & Miscellaneous (Subchapter I)	Possibly allowed, but a fire watch is required. Per Subpart 97.27-5.
Bulk & Dangerous (Subchapter O)	Not allowed per Subpart 151.45-2 (Prohibition against open lights if cargo is flammable)
Passenger (Subchapter H)	Possibly allowed, but a fire watch is required. Per Subpart 78.30-20.
Small Passenger (Subpart T)	Possibly allowed. No specific requirements for a fire watch nor ban against open lights.
Uninspected (Subpart C)	Possibly allowed. No specific requirements for a fire watch nor ban against open lights.

AIR POLLUTION REGULATIONS

Federal

The primary legislation governing air pollution is the Clean Air Act (CAA) of 1955 and its numerous amendments. These regulations govern the emission of air pollutants to protect human health and the environment. The CAA does not regulate incinerators with input capacities of less than 100 tons/day of waste; hence, a burn barrel would not appear to be subject to the CAA. Apparently, unless a burn barrel is operated near a U.S. Port, federal air pollution regulations will not apply due to the small amount of discharge anticipated during burning. Even though the U.S. Environmental Protection Agency's (EPA) regulatory jurisdiction extends 12 miles from shore, the agency is reportedly not concerned with regulating "small sources" such as these (EPA 1989b). Telephone conversations with EPA personnel in Seattle (EPA 1989a) indicate that presently, the agency has no plans to regulate the at-sea burning of shipboard-generated wastes. If EPA decided to promulgate such regulations, the process would take at least two years.

In the late 1970s and early 1980s, the EPA was involved in at-sea incineration of hazardous wastes. The regulatory framework was provided by the U.S. Ocean Dumping Act (formally called the Marine Protection, Research, and Sanctuaries Act of 1972, as amended) and the London Dumping Convention (formally called the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972). To obtain an ocean incineration permit, the following issues had to be addressed: waste destructibility; incineration system, proposed at-sea burn site, environmental effects; needs assessment; and other impacts. The incineration equipment, the vessel, the waste characteristics, and contingency plans were also important. Environmental concerns centered on the potential for spills of liquid hazardous wastes at shore-side storage facilities and at sea, with subsequent environmental damage. However, this prior experience does not relate to burn barrels: the wastes under consideration for burning were hazardous and/or toxic. Furthermore, the quantities of waste were considerably larger than that contemplated for burning in burn barrels.

State and Local

Although EPA regulations do not currently appear to apply to burn barrels, the CAA generally delegates to state and local governments the responsibility for preventing and controlling air pollution. Thus, the regulations of individual states and local air pollution control agencies may apply to shipboard combustion sources in coastal waters. These regulations vary both in area of jurisdiction (distance from shore) and severity (allowing or prohibiting open burning).

In the Seattle, WA area, the Puget Sound Air Pollution Control Agency (PSAPCA) regulates emissions from boilers in port and in near-shore waters, based on visual (opacity) standards. In Washington State, the local air pollution control agencies' jurisdiction extends to the appropriate County line. For example, where several counties border Puget Sound, PSAPCA's authority extends only about one mile offshore. For others, the jurisdictional boundary is 12 miles offshore (OAPCA 1989).

Other states have varying regulations. For example, at the present time, the State of Texas does not have regulations which would affect the use of burn barrels. The State has not and is not planning to develop air pollution regulations for marine vessels (Hartsock, 1989).

However, Massachusetts, like the State of Washington, could choose to enforce a general regulation regarding the generation of pollutants if a vessel operator chose to burn in a Port. It would be prudent if a vessel operator did not burn waste in Port without checking with local Air Quality authorities first (Squires, 1989).

The State of Louisiana is yet another indication of the diversity of regulatory enforcement. According to Louisiana State Regulation III.11.09, "Control of Air Pollution from Outdoor Burning", it is illegal to burn waste in open barrels anywhere within the State, including the State's 12-mile boundary extension into the ocean. The State will actively prosecute violators of this law. Additionally, violators could also be charged with violating the State's Solid Waste Regulations which prohibit the burning of solid waste (Pritchard, 1989).

In California in 1984 the Air Resources Board (ARB) staff drafted a legal opinion which concluded that the State of California, acting through the ARB and the Air Pollution Control Districts (APCDs), possesses the legal authority to regulate emissions from marine vessels. (Report to the California Legislature on Air Pollutant Emissions from Marine Vessels - Air Resources Board, June 1984). California coastal waters extend three miles from shore, and the federal government exercises jurisdiction over the "contiguous zone," i.e. waters from three to twelve miles from shore. The California Supreme Court determined that the state's ability to protect and enhance air quality within its territory is dependent to some degree upon its ability to control emissions from marine vessels operating beyond its territorial waters. Meteorological data demonstrates that marine vessels emitting air pollutants outside the territorial limits of the state can impact air quality in the coastal districts, and seriously inhibit the ability of the districts to attain mandated federal and state standards. The boundaries of California's coastal waters range from 27 to 102 miles off-shore. Currently there is no rule in California which gives the ARB or AQCDs the authority to enforce marine vessel emission standards. A rule is currently being drafted, and is expected to be presented for approval in April of 1990. Until a state rule is approved, California will follow EPA standards.

New Jersey is similar to the States of Washington and Massachusetts, in that the State has general air pollution regulations that prohibit open burning, but would be unlikely to enforce them, unless on operator was burning in a harbor. State officials suggest checking with local authorities before burning (Applegate, 1989).

These regulations vary significantly in range of jurisdiction, prohibitions, and emissions limits. Therefore, it is recommended that ship operators verify the regulations of the local air pollution control agencies in the states whose coastal waters and ports they frequent.

SECTION 4

EXISTING SHIPBOARD WASTE DISPOSAL TECHNOLOGIES

ALTERNATIVES TO BURN BARRELS

Compactors

Compaction makes garbage easier to store: compacted waste occupies less space and is less unsightly. The compaction process compresses waste into bags, boxes, or self-contained briquettes. If not malodorous, compacted wastes can be stored for disposal at port reception facilities. Alternatively, compacted wastes can be disposed of in certain MARPOL-designated zones. Because of their higher density, compacted wastes are more likely to sink. The U.S. Navy currently uses seven different brands of trash compactors.

Comminutors and Grinders

When not in a "special area", MARPOL Annex V regulations permit the discharge of food wastes, non-plastic, and non-floating garbage which have been ground or comminuted to 25 mm (one inch) or smaller. Food waste grinders produce a slurry of food particles and water. Comminution of paper, rags, metal, glass, and crockery requires large, specially designed equipment.

Marine Incinerators

Marine incinerators are somewhat less sophisticated than their land-based counterparts. They are usually hand-stoked (i.e., waste must be manually loaded). Marine incinerators have combustion air fans to promote better burning, and some require auxiliary fuel such as diesel fuel. Because of their refractory lining, the skin temperature of these units is relatively low, an important safety feature. A marine incinerator will probably have lower particulate and carbon monoxide emissions than a burn barrel, due to its forced combustion air fan and heat-retaining refractory. However, hydrogen chloride (HCl) emissions will be the same, since neither unit has any acid gas scrubbing mechanism. Marine incinerators range in cost from $10,000 to over $30,000, depending on capacity (TeamTec).

Recycling and/or Disposal in Port

While wastes can be stored for recycling or disposal in port, there are numerous conditions that make this impractical. The primary problem with holding wastes for disposition ashore is storage space, which is at a premium aboard ship. Aesthetics and odor are also concerns of crew members who would have to live and work in close proximity to stored garbage. Stored wastes also pose a fire hazard.

Public Law 100-220 requires ports to ensure that reception facilities for all shipboard wastes, including APHIS-regulated wastes, are available. For APHIS wastes, these can include steam sterilization, grinding/comminution,

or incineration facilities. A major concern with shore-side disposal is adequate separation of "normal" wastes from APHIS wastes, with proper handling and disposal of each of these waste streams.

A wide variety of shipboard wastes could theoretically be recycled, including metals, glass, paper, and plastics. However, the money (if any) obtained for recycling these materials is unlikely to adequately compensate a vessel operator for the expense of sorting, storing, and delivering these materials to a recycling center.

SECTION 5

DESIGN GUIDELINES FOR BURN BARRELS FOR SHIPBOARD WASTES

TYPES OF SHIPBOARD WASTES

Wastes Suitable for Burning

As an alternative to disposing of foreign food-contaminated plastics in port under USDA supervision, vessel operators may choose to burn these plastics. Paper, cardboard, and rags can be burned along with the plastics to promote smoother combustion. Alternatively, these materials may be discharged in other than "special areas" more than 12 nautical miles from shore (see Table 1 for specific details).

Floating dunnage such as wood, lining, and packing materials must be dumped 25 nautical miles off shore. Paper, rags, and food that are comminuted or ground to one inch (25 mm) or smaller may be dumped beyond three miles. Since glass, ceramics, and metals are incombustible, they may be dumped at sea beyond 12 nautical miles or disposed of properly onshore.

Since plastics are a primary concern from an environmental (ocean pollution) standpoint, and food-contaminated refuse is important from plant and animal disease and human health standpoint, these wastes are logical candidates for disposal by burning at sea.

Wastes Not Suitable for Burning

Certain types of waste are extremely dangerous and must not be burned in a burn barrel. These include aerosol cans and sealed containers such as paint cans or jars containing liquids, since there is a high risk of explosion and injury from flying debris. Flammable and combustible liquids such as gasoline, kerosene, paint thinner, and other petroleum products pose a severe fire and explosion hazard as well, and must not be burned. These types of garbage must be stored and disposed of ashore.

Because a burn barrel is not a sophisticated, high technology piece of equipment, complete combustion is unlikely. Noxious fumes and gases are not cleaned up before they enter the atmosphere, presenting a potential danger to the crew and the environment. By taking the precautions outlined in this document, potential health and safety risks to the crew can be minimized. Because of the relatively small amounts of waste being burned and the large amount of dilution of the burn barrel fumes, the impact on the environment from burn barrel operation is expected to be minor.

DESIGN CRITERIA

Configuration, Materials of Construction, and Size

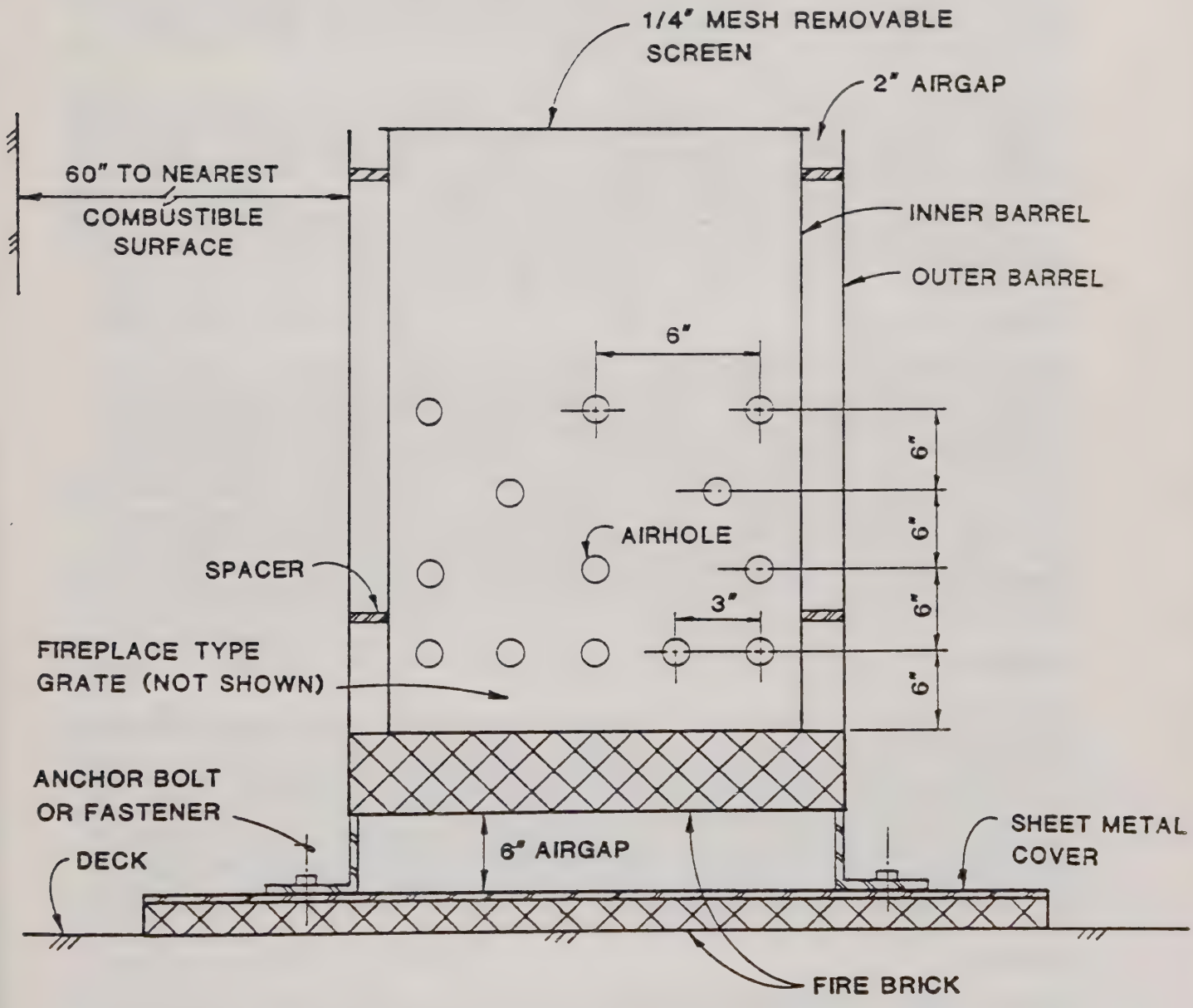
For fire safety reasons, burn barrels should be constructed of steel and be of sufficient thickness to prevent premature burn-through and warpage. One possible configuration is a vertical barrel, similar in shape to the familiar 55-gallon drum. To minimize the chances of burns from contact with hot surfaces, a "barrel within a barrel" configuration is preferable (see Figure 1). Metal spacers should be used to maintain at least at least a one inch air gap between the inner and outer barrels. This air gap should help keep the outer barrel cooler and afford some additional protection against burns.

An open-top, 55-gallon drum may be used as a prefabricated inner barrel. It is recommended that drums conform to U.S. Department of Transportation specifications (49 CFR 178.115-118). A drum meeting DOT specification 17C is preferred. Such a drum is made of 16 gauge steel and is less likely to burn through than one of 18 gauge steel that meets specifications 17H or 17E. Drums without rolled (reinforced) top and bottom rims should be avoided, as they are not as strong and may dent or collapse more easily. An 85-gallon steel "overpack" drum, used in the hazardous waste industry as a secondary containment for waste-filled drums, can be used as a prefabricated outer barrel. The overpack drum's 26-inch inner diameter allows about a 1.5-inch air gap all around the inner drum, which has about a 22.5-inch inner diameter. The 85-gallon overpack is about 3.4 inches taller than the 55-gallon drum; however, when insulating materials such as fire brick or refractory cement are placed underneath the inner barrel, the top rims of both drums will be at approximately the same height. The overpack drum should also meet spec 17C. A new 17C 55-gallon drum costs about $35 to $42, while a new 17C 85-gallon overpack ranges from $76 to $120 (Unitech, 1989).

If a 55-gallon drum is used, it should be thoroughly cleaned to remove any chemical residues which could produce noxious or toxic fumes when a fire is burned inside. For the same reason, any painting or coating on the drum should be removed by grinding or sandblasting prior to burning. To minimize corrosion, heat-resistant paint can be applied to the exterior of the drums, if desired.

The burn barrel should be large enough to burn the expected volume of wastes in a reasonable time. The diameter of the barrel should be large enough so that a full garbage sack cannot block the barrel, preventing smoke and gases from escaping. The barrel should be small enough to preventing occupying too much valuable deck space. If the ashes are to be emptied by tipping the barrel, the barrel should be small and light enough to make this convenient and safe. Alternatively, a removable ash pan could be provided in the bottom of the burn barrel, or an ash scoop or shovel can be used.

The design should include a spark arrester to prevent sparks and embers from being carried out of the burn barrel and injuring crew members or causing fires on deck. The spark arrester should be constructed of heavy wire mesh with openings not larger than 1/4 inch. In addition, a steel or



SCHEMATIC OF BURN BARREL

NOT TO SCALE

Figure 1

PRELIMINARY DRAWING
NOT FOR CONSTRUCTION

cast iron grate, similar to those used in fireplaces, should be provided to keep waste off the bottom of the barrel and prevent burn-through. Rebar inserted through holes in the sides of the barrel and arranged like wheel spokes could also serve as a grate.

In addition, a sheet metal cap should be fabricated to keep rain out of the burn barrel when not in use. It should not be used to snuff out an out-of-control fire, as this will cause "puffing" of smoke out the air inlet holes. The cap can be similar to a garbage can lid and should have fasteners to keep it in place in rough seas.

Because of its strength and resistance to warping in the presence of heat, steel is the preferred material of construction for burn barrel components. However, corrosion from salt water and spray is likely. Heat resistant paints may help prevent some corrosion. However, it would probably be more cost effective to discard and replace some parts, such as the spark screen, rather than attempt to prevent corrosion by using more exotic materials or coatings.

Alternate Designs

Some vessels have apparently used 55-gallon drums mounted on gimballs attached to the bulwarks. The bottoms have been cut out of these burn barrels and replaced with a metal mesh or grate. Since the barrels are suspended over the water, ash falls directly into the sea. This may be a safe design in that it minimizes the chances of burns from contact with the hot barrel, and simplifies ash removal. In some instances, these barrels are used to burn only paper and cardboard, which poses no problem. However, if plastics are burned and any globules of melted plastic are produced, these could fall into the water, a violation of the MARPOL regulations.

Combustion Air Inlets

Inlet holes for combustion air should be provided on the sides of the inner barrel, near the bottom rim and extending about halfway up the sides (see Figure 1). This will allow a cleaner-burning fire by allowing air to reach the burning material more directly than through the top of the barrel. As the air passes downward in the space between the barrels, it is preheated. The lower holes will direct air to the burning wastes, while the upper holes direct air to the resulting combustion gases. These three factors all contribute to better combustion.

Anchoring

The burn barrel should be anchored in such a fashion that it will not tip over in rough seas. This serves to prevent both physical injuries from a unit that breaks loose, as well as preventing burning material from being spilled from a barrel that has tipped over. Clamps or clips that bolt to the deck or the railing are possible methods of securing the burn barrel.

Clearances

Fire danger is probably the most important safety concern related to the use of burn barrels. To develop recommended safe clearances from combustible surfaces, energy extension service bulletins describing the proper installation of solid fuel burning appliances (e.g., "wood stoves") were consulted (WEES 1987). The National Fire Code and Uniform Mechanical Code contain similar information. The King County (Seattle area) Building Department was also contacted (King County, 1988).

When installed on a steel deck, it is recommended that the bottom of the burn barrel be at least six inches above the deck, allowing air to freely circulate beneath the barrel. This air flow should provide cooling and minimize heating of the deck. A deck made of combustible materials such as wood or fiberglass should be protected by at least two inches of closely-spaced solid masonry units or other insulating material suitable for outdoor use. The insulation should be covered with 24-gauge sheet metal cover. The insulation and sheet metal cover should extend at least 18 inches beyond the burn barrel on all sides.

Burn barrels must be located at least 60 inches (five feet) away from all bulkheads and other vertical combustible surfaces. They should not be located beneath overhead combustible surfaces. They should also be located away from those materials such as steel and aluminum that are subject to corrosion by acidic gases which result from burning plastics.

Each vessel and burn barrel will present unique installation and operating conditions. To assure a safe installation, consultation with a naval architect or marine engineer who is knowledgeable about fire protection is strongly advised, prior to installing a burn barrel. In addition, notification of the insurance agent is highly recommended to verify that the vessel's insurance policy covers such an installation.

Burn Barrel Location

Burn barrels should be located in an open, well-ventilated space, not in an enclosed compartment where smoke and fumes could lead to asphyxiation. To prevent the crew from inhaling flue gases and smoke, the burn barrel should be located on the after deck of the vessel. Thus, barring adverse wind conditions, the flue gases should be blown away from the crew if the vessel is underway. Furthermore, to prevent exhaust gases from being sucked into crew quarters or the engine compartment, the burn barrel should be located away from vessel air intakes.

On research vessels that must stay on station for extended periods, keeping the burn barrel downwind of the crew may be more difficult than on vessels that are generally underway. Coordination of burning with deck operations can alleviate some of these problems.

Some vessels may have insufficient deck space for safe burn barrel operations. For example, fishing vessels less than 120 feet in length may have too little aft deck space to allow burn barrel installation (Fisher, 1989).

To prevent ignition and explosion of gasoline vapors, burn barrels should not be installed on the aft deck of ships, such as research and fishing vessels, which refuel motor launches from aft deck gasoline storage tanks.

Auxiliary Equipment

For a safe installation, appropriate fire fighting equipment is an absolute necessity. A nearby fire hose with an adjustable spray/fog nozzle is a good choice, since it is less likely to freeze and can provide a greater fire-fighting flow than an extinguisher. A fire extinguisher suitable for Type A fires (ordinary combustibles such as wood, paper, rubber, and many plastics) should also be located nearby. If the extinguisher contains water or other liquids, it should be protected from freezing. The choice of extinguisher type and size should be approved by the vessel's insurance carrier prior to installation.

A first aid kit should also be readily available. It should contain materials specifically for the treatment of burns. At least two crew members should be trained in proper first aid techniques for burn victims. A poker, tongs, and ash shovel or scoop should be provided to assist in loading, turning, moving, and agitating materials to be burned.

INSURANCE CONSIDERATIONS

A number of insurance carriers that write marine insurance were contacted regarding their views of burn barrels and the potential underwriting risks (L. Johnson 1988; R. Johnson 1989; Wilton 1989). Most stated that the risk of fire was their major concern, because of the difficulty of fighting fire at sea and the difficulty of escaping from the fire. While a few companies said that they would need more information regarding the specific burn barrel installation before underwriting a vessel, most indicated they would rely on the judgment of a marine surveyor as to whether the installation were safe or not.

Marine surveyors are independent agents or companies that inspect vessels and cargo. They are experts in the operation of vessels and their associated equipment. Among their duties is to list the type and location of safety equipment such as fire fighting equipment. One marine surveyor contacted (Pruett, 1988) cautioned about choosing fire extinguishers to avoid freezing during cold weather. Another surveyor (Thurston, 1989) expressed concern about fire hazard, cramped decks on smaller vessels, and the problems of operation in high seas.

None of the insurers or surveyors indicated a first-hand knowledge of any burn barrel installations. It should also be noted that some insurance companies insure only the cargo, while others insure only the vessel itself. This is not expected to have a major effect on the insurability of a vessel, since fire danger to the vessel represents a danger to the cargo as well.

Because the installation of shipboard burn barrels is apparently a new phenomenon, vessel owners or operators would be well advised to consult with their insurance carriers before installing a burn barrel, rather than

risk loss of insurance coverage. Furthermore, the insurance company and/or its marine surveyor may have specific recommendations or requirements for the design, location, or operation of the burn barrel, as well as fire-fighting equipment.

COST CONSIDERATIONS

Estimating the cost of constructing and installing a burn barrel was beyond the scope of this investigation. However, a preliminary estimate indicates that an expenditure of about $200 for materials and $300 for labor could be expected. If the vessel operator provided the labor and/or utilized used drums, the costs could be lowered substantially.

A recent discussion with a Port of Seattle official (Aggerholm, 1989) indicates that Seattle and other ports are not expecting large quantities of shipboard wastes to be disposed of ashore, mainly because of the cost of disposal. Aggerholm expects most vessels will either dispose of their wastes in the ocean or return it to their home ports, where disposal may be less expensive than at U.S. ports. He also indicated that about 1,000 pounds of APHIS-regulated wastes were disposed of by a Seattle firm for about $300 in truck-mounted unit fitted with steam pipes.

For comparison, the payback period for a $500 burn barrel was calculated. A daily waste generation rate of 0.26 pounds of plastics and 4.14 pounds of "international" garbage was assumed per person (Port of Seattle, 1988). For a crew of 30, this amounts to 132 lb/day, or 660 pounds for an average five day trip. At 30¢/lb, shore-side disposal would cost $198. Thus, the capital cost of a burn barrel would have a simple payback period of only 2.5 trips. For smaller crews or shorter trips, the payback would be lengthened. Conversely, if the burn barrel cost less than $500, payback would be shortened.

A recent check of equipment prices showed a marine incinerator with a 200 liter (about 177 pounds of garbage at 25 lb/cu ft) cost about $21,000 and a 400 liter incinerator cost about $26,000 (Golar, 1988). Clearly, the costs involved with installation of a marine incinerator are over an order of magnitude higher than a burn barrel. While a marine incinerator can provide more complete burnout of wastes, it will probably produce the same amount of acid gas emissions from plastics. Furthermore, many marine incinerators require diesel or waste oil as fuel.

SECTION 6

OPERATIONAL GUIDELINES

WHEN TO BURN

Vessel Location and Waste Types

Choosing the proper time to burn wastes is largely a matter of common sense. Figure 2 shows the various questions about waste types and vessel location that should be asked prior to burning accumulated wastes.

Frequency of burning depends in large part on how much storage capacity the vessel has for wastes, and how much time can be spent burning on any one day. Thus, a vessel with a large storage capacity could burn much less frequently than one with little room for waste storage. Because of the time involved in building a fire properly, it is recommended that a volume at least equal to six large (39 gallons) plastic garbage sacks be available before being burned.

Sea and Weather Conditions, Time of Day

To minimize the chances of the burn barrel tipping over or injuries to the crew during loading and burning operations, burn barrels should be used only when relatively calm sea conditions prevail. The wind and vessel direction must be such that smoke and exhaust gases from the burn barrel are blown towards the stern and away from the crew and vessel. Burning during heavy rainstorms should be avoided, since the rain will tend to wet the waste and cause increased smoking. Another consideration may be vessel operations; for example, a preferable time to burn would be when deck operations are at a minimum.

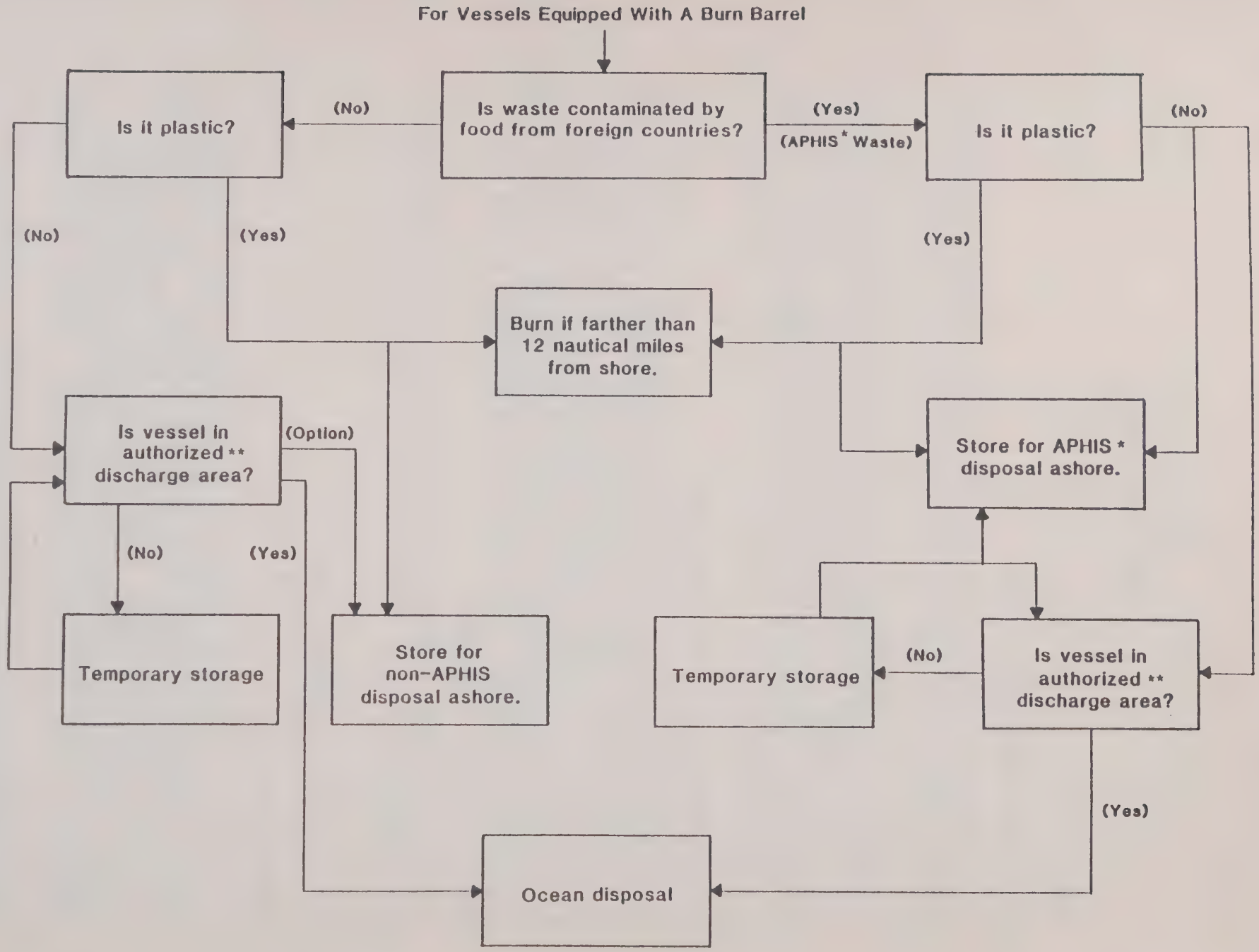
If wastes are burned at night, the area around the burn barrel must be well-lighted for operator safety and to allow proper observation of the burning process.

HOW TO FIRE A BURN BARREL SAFELY

Building the Fire

Building a fire in a burn barrel is similar to using a fireplace or wood stove. A pile consisting of kindling or small wood scraps and crumpled paper or newspaper should be built on top of the grate. Some vessels have pallets or other wood dunnage; vessels lacking this supply of wood can use corrugated cardboard instead. These materials should be ignited with a match or burning piece of paper, *not with a flammable liquid such as gasoline* as is the reported practice aboard some vessels. As the paper and wood begin to burn, cardboard or additional paper and wood can be added.

Plastics have a relatively high heat content (they "burn hot"). Plastics can be added after the fire is well-established (i.e., not smoking heavily). Plastics must be added to the fire slowly. If too much plastic



* APHIS - USDA Animal and Plant Health Inspection Service

Figure 2

is added at once, the temperature of the fire will drop and the burn barrel will smoke excessively. However, once the plastics begin burning, the fire can grow very rapidly and may accelerate out of control.

Plastics should be fed slowly and in small amounts on a regular basis, rather than infrequently in large batches. It is recommended that plastics be fed roughly five gallons (loosely packed) at a time. By way of reference, a typical household plastic garbage bag holds 33 gallons; a lawn and leaf bag holds 39 gallons.

Systematic feeding of small amounts of plastics will allow them to burn rather than melt into globs that fall to the bottom of the barrel and remain unburned. These plastic globs cannot legally be disposed of at sea and must be separated before the ash is discharged. Hence, patience on the part of the operator is important and can save time in the long run.

Wastes not Requiring Burning

Glass and metal do not burn and they create additional ash requiring disposal. When farther than 12 nautical miles from shore, it is permissible for them to be dumped. Meat and vegetable food scraps do burn, but slowly, and may cause the burn barrel to smoke. Since they can legally be dumped outside the 12-mile limit, the operator may choose not to burn them.

Difficult Wastes

Wet wastes are difficult to burn; these include food scraps, wet rags or paper towels, and discarded fishnets. They should be fed into a well-established fire; this allows the heat to dry them off before subsequent burning can take place. Large or bulky items such chunks of wood or stacks of newspaper do not burn well unless they are broken into smaller pieces or agitated to expose more of their surface to the flames.

Dangerous Wastes

Certain wastes are extremely dangerous to burn. These include aerosol cans and flammable or combustible liquids such as gasoline, kerosene, diesel fuel, or other petroleum products. These must not be burned in the burn barrel, as they present a real risk of explosion or uncontrolled fire. They can result in explosions, fires burning out of control, or literally burn outside the barrel. Any closed container containing a liquid (e.g., paint cans) presents an extreme explosion hazard, since the liquid can turn to steam, expand, and explode the container. Aerosol cans may turn into flame throwers when ignited. These types of wastes should not be burned under any circumstances.

Maintaining Good Combustion Conditions

Adequate air must be supplied to the fire at all times. This can be accomplished by making sure the barrel's air inlets are never blocked by waste inside the barrel or by objects outside the barrel. The waste should also be agitated frequently with a steel poker. This breaks up the wastes

into smaller pieces that are more easily burned. In addition, it exposes new surfaces to the flames and allows them to ignite. It also provides a pathway for air to enter from above. Wastes in the barrel that are slow to ignite should be turned over with the unburned face down.

Upset Conditions

Upset conditions are conditions which are not ideal, could lead to dangerous situations, or are already dangerous. The following are some examples of upset conditions and recommended responses:

- A large bag of wet waste is added to the barrel, causing excessive smoke. Not much can be done once the waste is in the barrel, other than to agitate it frequently with a metal poker to promote drying and igniting of the waste. It should not be removed from the barrel, as this could spread glowing embers or otherwise start a fire on deck.

- A large amount of plastic is added to the barrel. Due to the high heat content of the plastics, the fire accelerates and the barrel overheats (glows red). Flames may be shooting out of the top of the barrel. In this case, the fire should be slowed down by quenching with small amounts of water from a nearby fire hose.

- The burn barrel overturns. The anchoring system should be designed to prevent this from happening. If, however, the barrel does overturn, the burning waste should be extinguished immediately using standard shipboard fire-fighting techniques and equipment.

Completing the Burndown of Wastes

The waste pile in the barrel should be agitated frequently with a metal poker. Many pieces of waste will only char on the outside and not burn out completely unless they are turned with a poker. Breaking them up and exposing new surfaces to the flames aids in combustion. After the last waste is loaded, it is especially important to break up and agitate the wastes to bring about as complete a burnout as possible. It is possible that the barrel will stay warm for several hours after the last waste is loaded.

Ash Disposal

Maintaining a bed of ash, two to three inches thick on the bottom of the barrel, beneath the grate is desirable. This layer of ash protects the metal bottom of the burn barrel from heat damage, corrosion, and erosion by the fire and associated chemicals and exhaust gases. Initially, a bed of clean dry sand could be used for this purpose.

Ash should be removed from the barrel before it builds up enough to obstruct the combustion air inlets on the lower sides of the barrel. Ash should be disposed of in accordance with the MARPOL Annex V regulations, specifically with regards to the distance from shore. If the burn barrel does not have a removable ash pan, the use of an ash scoop or shovel will prevent having to lift the barrel and empty it over the side of the vessel.

It is important to note that melted-down globs of plastic are still considered to be plastic; hence, they cannot be legally disposed of at sea. Separation of these plastic globs from the other ash is required before the other ash can be dumped at sea. If this is not convenient, the entire supply of ash should be stored in a non-combustible container (e.g., metal garbage can) and disposed of properly ashore.

HUMAN HEALTH AND SAFETY CONCERNS

As with any other piece of heat-producing equipment, certain safety precautions must be followed to minimize the chance of health or safety problems to the operator or nearby persons.

Burns

The surfaces of the burn barrel are likely to be hot, and physical contact with them could result in burns. The suggested "barrel within a barrel" configuration is intended to provide a lower outside surface temperature on the barrel, but caution is still advised. The operator is advised to wear leather gloves and a long-sleeved shirt to provide some additional protection. Avoiding contact with the hot surfaces of the barrel is the best way to avoid being burned. At least two crew members should be trained in first aid and be able to treat burns.

Eye Injuries

Safety glasses or goggles should be worn by burn barrel operators to prevent eye injuries or smoke irritation.

Contact with Wastes

Handling garbage and wastes always poses the risk of cuts, punctures, and infection. Therefore, commonsense precautions must be taken. These include wearing leather gloves and washing all parts of the body that come into contact with the waste. If dusty wastes are involved, a dust mask should be worn.

Inhalation of Smoke and Fumes

Smoke inhalation can cause respiratory irritation and/or damage. Smoke also irritates the eyes and can cause temporary vision problems which could in turn pose navigational hazards. To minimize the possibility of smoke inhalation, the burn barrel should be located on the after deck and used only when wind conditions will blow the smoke away from the vessel. The burn barrel operator and other crew members should obviously avoid areas where burn barrel smoke is present.

Even when there is little or no visible smoke, fumes from the burn barrel can pose health risks. Carbon monoxide is a clear, odorless gas resulting from incomplete combustion. If excessive amounts are inhaled, death can occur. The operator and crew should stay upwind of the burn barrel as much

as possible. The operator should stay away from the burn barrel except when loading or agitating the waste; however, the operator should maintain line-of-sight contact with the barrel.

Plastic items may contain chlorine, which when burned can form hydrogen chloride gas (hydrochloric acid). Hydrochloric acid is corrosive to lung tissue as well as to metals. Garbage that has been soaked in salt water also contains chlorine and presents the same problem. Therefore, with plastic items such as nets, floats, and styrofoam, it may be reasonable to store these items and dispose of them properly ashore. The same precautions for avoiding smoke and carbon monoxide problems are applicable.

Proper location and operation of the burn barrel is the most effective way to prevent health and safety problems.

Tipping and Lifting Hazards

The anchoring system should be properly designed to minimize the chances of the burn barrel tipping over or breaking loose while underway. If an ash scoop or shovel is used to remove ash rather than tipping the barrel over the side, the chance of injury to crew members is less likely.

Fire Hazards

Proper location and operation of the burn barrel is the most effective way to minimize fire danger. Careful loading of wastes, and avoiding the dangerous wastes listed above, are essential to preventing out-of-control fires in the burn barrel.

It is prudent to hold periodic fire drills and to have established procedures and assigned duties for crew members in case of fire. An Action Sheet listing actions such as alerting or waking the crew, making radio contact with the Coast Guard, etc. should be developed and posted.

Ingestion of Food Cooked Over Burn Barrels

While it may seem obvious, no one should cook any food over the burn barrel fire. Hazardous or toxic chemicals may be generated by the fire and could contaminate the food.

SECTION 7

ENVIRONMENTAL PROTECTION

ASH DISPOSAL

The ash resulting from proper burn barrel operations should consist only of sand, dirt, metal, and glass (all of which do not burn); small amounts of unburned carbon (similar in appearance to charcoal); and small globules of melted plastic. These melted-down globs of plastic are still considered to be plastic and cannot be legally be disposed of at sea. Separation of these plastic globs from the other ash is required before the other ash can be dumped at sea. If this is not convenient, the entire supply of ash should be stored in a non-combustible container (e.g., metal garbage can) and disposed of properly ashore.

For those barrels used only to burn paper and cardboard, the ash may be discharged directly into the sea.

AIR EMISSIONS

Chemistry of Waste Combustion

Wastes generated aboard ships exhibit the same general characteristics as domestic urban refuse. These shipboard wastes consist of such organics as paper, plastics, wood, food, and rags; and such inorganics as glass and metal beverage containers, broken small tools, etc. Such wastes typically have the following elemental analysis:

Carbon	20 to 30	percent
Hydrogen	4 to 6	percent
Oxygen	15 to 25	percent
Nitrogen	0.2 to 0.5	percent
Chlorine	0.2 to 2	percent
Moisture	10 to 30	percent
Ash	20 to 40	percent

In a combustion setting, the following oxidation reactions occur:

$$C + O_2 \Rightarrow CO_2$$
$$C + 1/2O_2 \Rightarrow CO$$
$$H_2 = 1/2O_2 \Rightarrow H_2O$$

A variety of emissions result from burning wastes, as described below:

Particulate Matter

Particulate matter (PM) is emitted as a result of incomplete combustion of fuel as well as entrainment of noncombustibles in the exhaust gas stream. Particles less than ten microns in diameter represent the inhalable fraction of PM emissions. (CARB, 1984) Federal, state, and local standards limit PM emissions to various concentrations (measured in grains per dry

standard cubic foot of gas, adjusted) or visual standards (opacity, measured in percent). Numerous particulate removal technologies exist, including fabric filters (baghouses), electrostatic precipitators, and wet scrubbers. Since burn barrels will not be equipped with any of these devices, control of PM will depend on conscientious operation. This includes feeding wastes at a moderate rate so that "smoking" is limited. Periodic agitation of the waste should promote more complete burnout. Mixing plastics with other wastes, rather than feeding large quantities of plastics at one time, will prevent too rapid combustion and subsequent entrainment of unburned PM.

It should be noted that marine incinerators, with their sophisticated air control, refractory lining, and auxiliary fuel burners will have lower PM emissions. However, this is obtained at significant increase in capital and operating cost over burn barrels.

Carbon Monoxide

Carbon monoxide is produced as an intermediate combustion product. When adequate combustion air and temperature are present, carbon monoxide is oxidized to carbon dioxide. Inhalation of excessive amounts of carbon monoxide can cause suffocation; this condition is unlikely in the open air of a ship deck, especially if crew members avoid breathing burn barrel exhaust gases by staying upwind. Carbon monoxide emissions can be minimized by promoting good combustion conditions through moderate waste feed rates and periodic agitation of the waste.

Hydrogen Chloride

From a pollutant formation perspective, the chlorine is an important waste component. The chlorine is found largely in plastics such as polyvinyl chloride (PVC) and as salt present in food wastes. Chlorine is also present as salt spray in the combustion air at sea. Chlorine acts as an oxidant, in a manner analogous to the oxygen in air. As the hydrogen found in all of the wastes prefers to oxidize with the chlorine rather than oxygen, the chlorine largely becomes hydrogen chloride through the following reaction:

$$H + Cl \Rightarrow HCl$$

This hydrogen chloride is a highly corrosive and undesirable combustion product. In incinerators, emissions of acidic gases such as hydrogen chloride are controlled by scrubbing the exhaust gases with water and/or alkali solutions such as lime slurries. This is done in devices such as wet or dry scrubbers.

In a burn barrel, which will not be equipped with such devices, HCl emissions can be limited somewhat by not burning chlorinated plastics. However, with the amount of chlorine present in both the combustion air and salted food, there will likely still be HCl emissions. Hydrochloric acid from the burning of certain plastics is not expected to adversely affect the ocean, which has a great buffering capacity and already has a significant chlorine content. However, due to HCl's corrosive nature, contact with the skin or breathing the vapors should be avoided. The barrel should

be located so that fumes do not contact surfaces sensitive to acid corrosion. Use of a marine incinerator instead of a burn barrel will not result in lower HCl emissions, since the former has no means of scrubbing out the acid gas.

Oxides of Nitrogen

Nitrogen in shipboard waste comes largely from food waste, typically in protein. The nitrogen is found in amine functional groups (i.e., $-NH_2$) and, in a combustion environment, reacts to form oxides of nitrogen (NOx). This fuel-derived NOx formation is largely not dependent upon temperature. Thermal NOx is generated at temperatures above 2700^{o}F, which are unlikely to exist in a burn barrel. NOx contributes to smog formation, which is unlikely to be a significant problem at sea. Use of a marine incinerator instead of a burn barrel will likely have no effect on NOx emissions.

Heavy Metals

Some metals can be vaporized at the temperatures existing in incinerators, and subsequently carried off in the exhaust gases. Metals of known toxicity which are commonly present in waste include arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. In the case of burn barrels, emissions of metals can be greatly diminished simply by not burning any metallic objects. Burning of flashlight batteries is particularly to be avoided, since they contain can contain nickel, silver, cadmium, mercury, and lead, depending on type. Furthermore, metal objects can be disposed of ashore or at sea in the designated areas. Use of a marine incinerator instead of a burn barrel will likely have no effect on heavy metal emissions.

Other Air Pollutants

The combustion of garbage can produce numerous other pollutants, especially in a low technology device such as a burn barrel, which lacks positive pressure air control and pollution control devices. These can include compounds such as polynuclear aromatic hydrocarbons (PAHs), dioxins (PCDD), furans (PCDF), and vinyl chloride. The toxicity of these compounds varies with the concentration, type, and length of exposure.

Since no burn barrels have reportedly been tested for air emissions while burning shipboard waste, no estimate of the types and amounts of pollutants is available. Hence, no risk assessment can be conducted to evaluate the potential dangers of exposure to and inhalation of air pollutants to humans in the vicinity of the burn barrel. This is an area where further research is needed.

Environmental Impacts

Combustion conditions in a burn barrel are closer to that of open burning than to those in an incinerator. Combustion air quantities are not controlled and the fuel (waste) is not metered. Burn barrels will have no post-combustion pollution control devices. However, due to the minimal waste feed rate, the airborne emissions are expected to be modest. The quantities of waste per barrel are expected to be relatively small, on the

order of several hundred pounds, rather than tons, per burn. Such feed rates and consequent emission levels are sufficiently low that air quality impacts from "burn barrels" operated on the open seas are not anticipated to be of significance. Vessels with burn barrels constitute small, widely dispersed "point sources" of air emissions. In addition, the gases emitted by a burn barrel are diluted to a great degree by the large volume of air above the ocean.

The environmental issues associated with "burn barrels" are more typically on the order of safety concerns such as contact with hot surfaces or breathing smoke and HCl fumes. Both concerns can be managed by operating the devices in a prudent manner.

CONCLUSIONS

Burn barrels can be constructed and operated in a safe, convenient, and cost-effective manner. However, use of a burn barrel requires a cautious and conscientious attitude. The MARPOL V guidelines and the Marine Plastic Control Act regulations provide various alternative methods of disposing of shipboard-generated waste.

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